WATER QUALITY FLAGGING

DEVELOPMENT OF
A METHOD FOR DETERMINING WATER QUALITY
AND IDENTIFYING POTENTIAL PROBLEMS

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Environment
Ontario

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WATER QUALITY FLAGGING -

DEVELOPMENT OF A METHOD FOR DETERMINING WATER QUALITY AND IDENTIFYING POTENTIAL PROBLEMS

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SUMMARY

This report describes a procedure for determining water quality and identifying potential problems based on conformance with Provincial Water Quality Objectives. An example of the application of this procedure using 1978 data at selected stations in the Lake Superior and Grand River drainage basins is included for illustrative purposes.

Water quality data deemed to be representative of conditions downstream of certain areas in the selected basins, and Objectives from the Ministry's publication "Water Management" were both input to computer programs which calculated the following statistics:

1) the percentage of test results at a station that did not meet the Objectives for a selected group of water quality variables (i.e. "pooled exceedence"); and

2) the percentage of test results at a station that did not meet the Objectives for a particular water quality variable (i.e. "percent exceedence").

The calculation of the above statistics and their application to identify water quality problems in a given area is known as the "flagging" procedure.

The flagging procedure proved to be an effective and easy to use method for identifying water quality problems in an area. The procedure may be applied both to individual stations and to large areas, such as drainage basins, depending on the type of detail required.

Some areas for improvement of the procedure were noted, such as:

1) the method of selection of representative stations and variables; and

2) the quantification of some water quality Objectives to enable flagging of more variables.

ACKNOWLEDGEMENTS

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The contribution of Regional Staff in collecting the water quality data used in this report and in providing technical assistance in station selection is sincerely appreciated.

1.0 INTRODUCTION

1.1 BACKGROUND

The 1974 report of the Implementation Task Force on the Capital Construction Program[1] suggested that the Ministry of the Environment (MOE) should develop a water quality index which could be used to describe general water quality in the Province. A subsequent report of the same committee[2] recommended that the Water Resources Branch investigate the practicality of such an index for Ontario and make recommendations on its implementation. A Water Resources Branch report[3] concluded that a water quality flagging method was preferable to an index. Senior management agreed to the water quality flagging procedure in principle and a proposal[4] for its development was submitted by the Hydrology and Monitoring Section of the Water Resources Branch and approved in 1977.

This report describes and evaluates the water quality flagging procedure developed by the Hydrology and Monitoring Section and presents an example of its application to determine water quality and identify potential problems using 1978 data at selected stations in Ontario.

1.2 THE WATER QUALITY FLAGGING APPROACH

The flagging procedure described herein can be used to identify water quality in a given area. The initial step, which consists of the selection and acquisition of a suitable data base, involves the choice of water quality variables, stations, time period and the consideration of data availability. Next is the selection of appropriate water quality Objectives to which individual test results are compared. For the present report, the Objectives used are contained in the publication "Water Management - Goals, Policies, Objectives and Implementation Procedures of the Ministry of The Environment"[5], and relate to two critical water uses, aquatic life and body contact recreation.

Water quality data and their respective Objectives are then both input to computer programs which perform the following calculations:

a) the percentage of test results at a station that does not meet the Objectives for a selected group of water quality variables (i.e. "pooled exceedence); and
b) the percentage of test results at a station that does not meet the Objectives for a particular water quality variable (i.e. "percent exceedence").

Application of the flagging program on a broad scale produces large volume reports. While this material is useful for answering questions concerning specific water quality, it is far too voluminous to be used in a report on water quality on a drainage basin level.

To obtain a more concise, summarized presentation, the results of the flagging program may be further manipulated by using SPSS[8] computer programs. These SPSS programs have many applications, such as the calculation of special statistics and frequency distributions, which assist in the interpretation of data.

There are several ways in which the flagging procedure may be applied to identify water quality in an area. The following approach, for example, could be used to identify non-conformance problems in a large area, such as a major drainage basin which has a large number of stations, each with data for several water quality variables:

1) tentatively identify where significant non-conformance problems occur by using the pooled exceedence statistic;

2) examine the non-conformance problems in the areas identified by the first step in greater detail by using the percent exceedence statistic to establish which variables are in non-conformance;

3) identify the magnitude and the specific location of non-conformance problems by using the percent exceedence statistic at an individual station level.

1.3 PROVINCIAL WATER QUALITY MONITORING NETWORK

The data for testing the flagging procedure were derived from the Provincial Water Quality Monitoring Network. The objectives of this Network are:

a) to ensure that the water quality Objectives of the Province are met for the various water uses (conformance); and

b) to determine water quality in the Province, and through continued surveillance, to provide data on which trends and/or new problems can be detected (surveillance).

The Ontario Water Resources Commission started the Provincial Water Quality Monitoring Network in 1964 by establishing water quality stations on 89 rivers and streams. By the end of 1965, the program was expanded to 210 water quality stations on 156 rivers and streams. During the initial years of the program approximately 20 water quality variables were sampled on a routine basis, 10 to 12 times per annum (Table 1).

By the end of 1978 the number of active stations had grown to 832 and provided a good coverage of the more densely populated areas of both southern and northern Ontario. Furthermore, the number of water quality variables analyzed on a routine basis had expanded to about 60 (Table 1).

Stations in the monitoring network measure the effects of a variety of point and diffuse sources. About 56% of the stations in the Province are recognized as being multi-purpose (e.g. a station downstream of both an urban area and a sewage treatment plant). The overall distribution of stations according to the station

TABLE 1. WATER QUALITY VARIABLES COLLECTED IN THE PROVINCIAL WATER QUALITY MONITORING NETWORK

Variable	1964	1978
temperature	X	X
dissolved oxygen	X	X
total coliforms	X	X
fecal coliforms		X
fecal streptococcus		X
Pseudomonas aeruginosa		X
biochemical oxygen demand	X	X
total phosphorus	X	X
soluble phosphorus	X	
filt. react. phosphorus		X
free ammonia	X	
filt. ammonia		X
filt. nitrate	X	X
filt. nitrite	X	X
total solids	X	X
suspended solids	X	X
conductivity	X	X
turbidity	X	X
chlorides	X	X
sulfate		X
unfilt. react. silicates		X
acidity		X
alkalinity		X
pH	X	X
iron	X	X
phenols	X	X
hardness	X	X
calcium		X
magnesium		X
colour		X
potassium		X
sodium		X
total organic carbon		X
chemical oxygen demand		X
solvent extractables		X
arsenic		X
mercury		X
aluminum		X
chromium		X
copper		X
lead		X
cadmium		X
zinc		X
manganese		X
nickel		X
fluoride		X
cyanide		X
cobalt		X
gross alpha (dissolved)		X
gross alpha (undissolved)		X
gross beta (dissolved)		X
gross beta (undissolved)		X
radium 226 (dissolved)		X
total uranium 238		X
cesium 137		X
cesium 134		X
cobalt 60		X
tritium		X
ABS	X	
total kjeldahl nitrogen	X	X
dissolved solids	X	X

classification system used in the Provincial Water Quality Monitoring Network is as follows:

Station Classification	Percent of Total Number of Stations
sewage treatment plants	19%
industries	10%
urban land uses	10%
agricultural land uses	2%
extractive industries (mining)	4%
transportation corridors	2%
relatively undisturbed land (background)	20%
mouths of major tributaries	11%
water uses (e.g. fisheries, water supply)	9%

The remaining 13% of the stations are operated for special purposes such as waste assimilation studies, conservation authorities, etc. Data obtained from the Provincial Water Quality Monitoring Network are published annually[6] and are also available on computer tape.

The rivers and lakes that have monitoring stations are listed in Appendix 6.1 for the major drainage basins shown in figures 1 and 2.

1.4 PROVINCIAL WATER QUALITY OBJECTIVES

The flagging procedure requires a set of numeric criteria (i.e. Objectives) that are used by the computer program for comparison to individual test results. The Objectives published by the Ontario Ministry of the Environment were selected for use in this report.

The MOE Objectives "... are a set of narrative and numerical criteria designed for the protection of aquatic life and recreation in and on the water. They represent a desirable level of water quality that the Ministry strives to maintain in surface waters of the Province."[5]

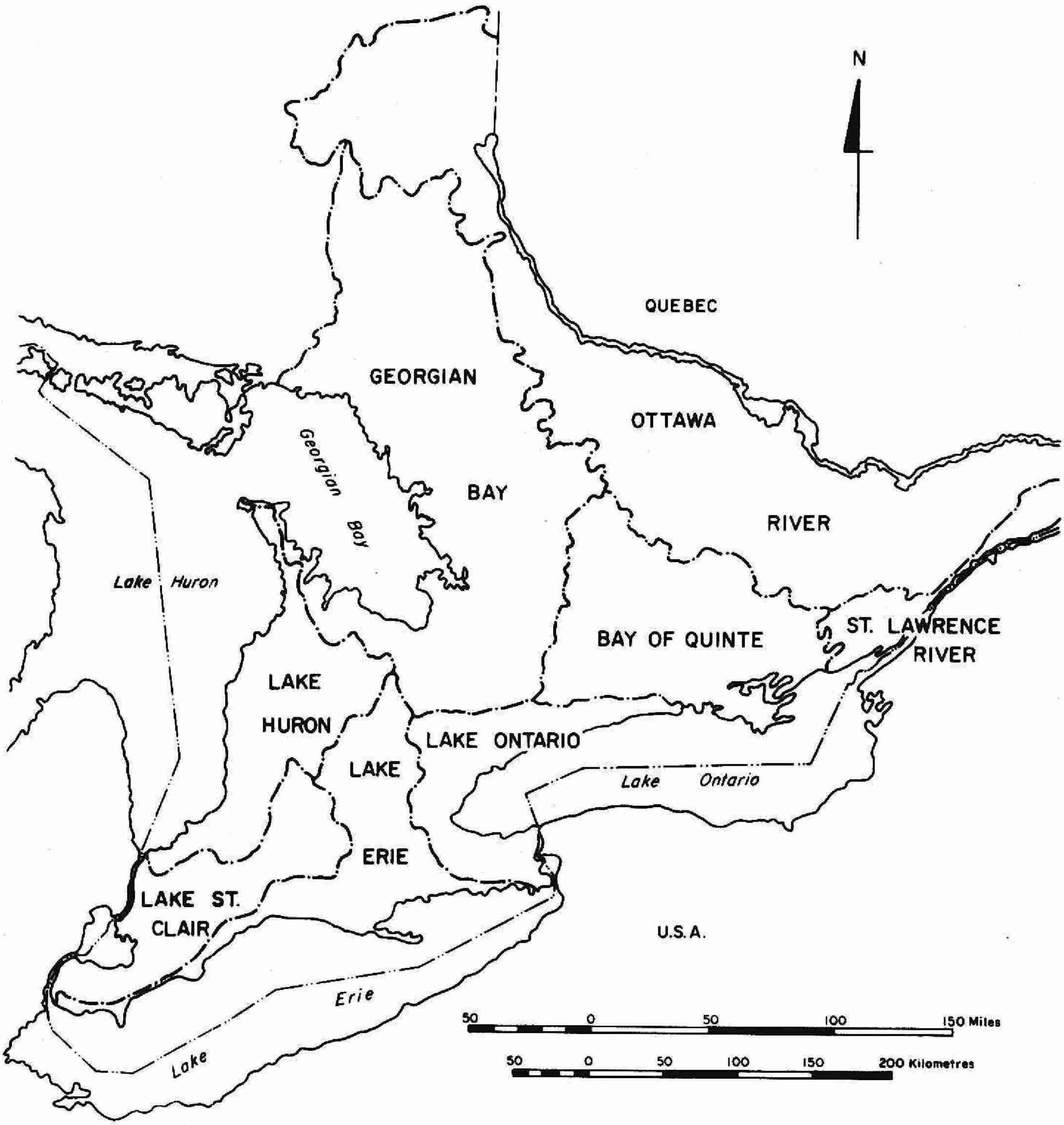


Figure 1. Major drainage basins in Southern Ontario.

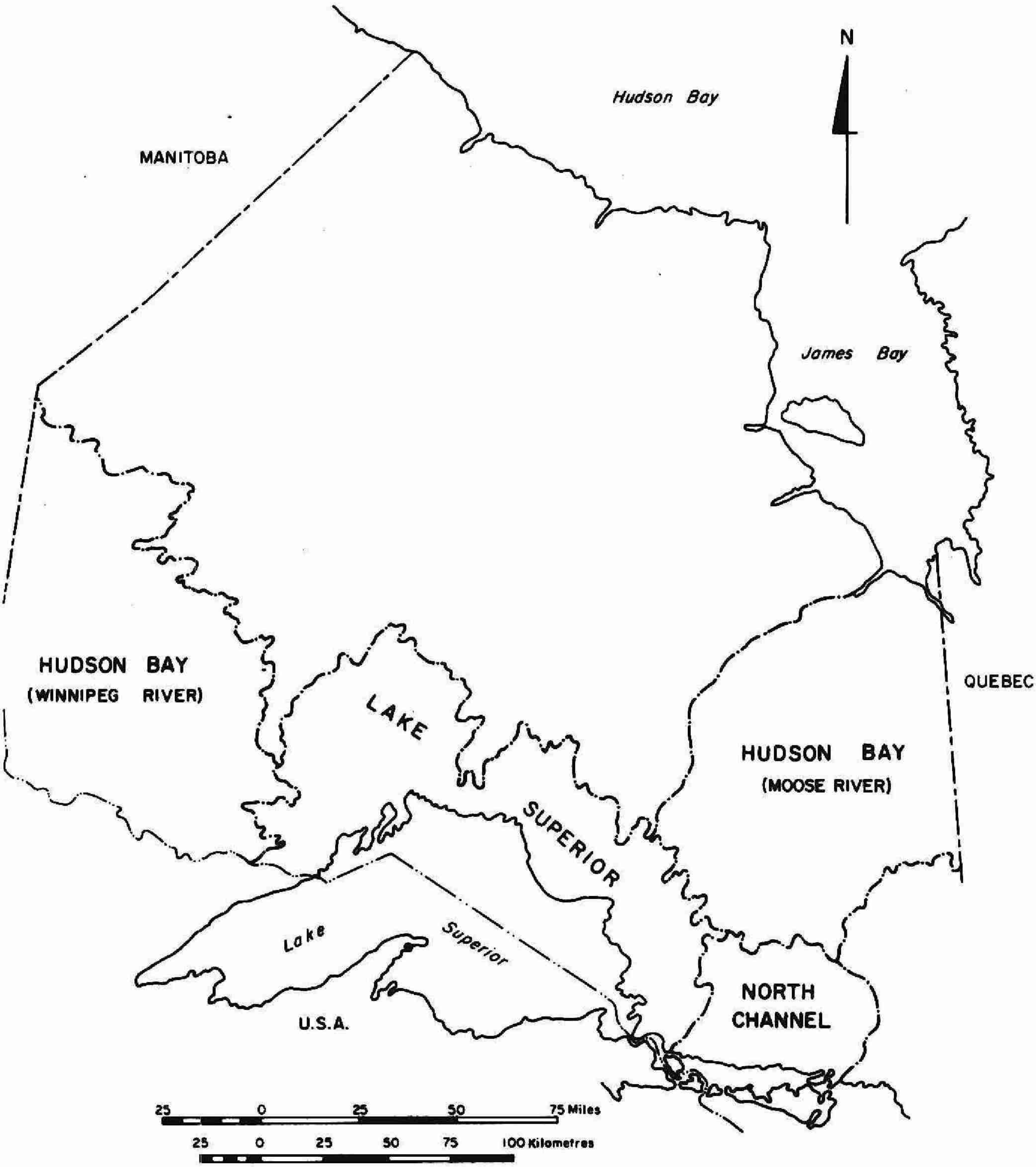


Figure 2. Major drainage basins in Northern Ontario.

The water quality Objectives used in this report were derived from short-term toxicity data and the use of "application factors". Each Objective was determined on the basis of a scientific rationale. For further information the reader should refer to the Ministry publication, "Rationale for the Establishment of Ontario's Provincial Water Quality Objectives"[7].

1.5 ELECTRONIC DATA PROCESSING

1.5.1 Sample Information System

Water quality data generated by the Provincial Water Quality Monitoring Network and other Ministry programs are stored in the Sample Information System (SIS). This system is a generalized, automated computer system designed to edit, store and retrieve water quality data. In order to perform the computations required for the flagging procedure, the SIS was expanded to include a "water quality criterion testing" section, hereafter referred to as the flagging program. This program was written and tested by the Systems Development Section under contract to the Hydrology and Monitoring Section.

The flagging program consists of three parts, as follows:

Part 1 - SIS selective retrieval;
Part 2 - tabular reports;
Part 3 - summary bar charts.

Part 1 involves overall data selection from the Sample Information System. Parts 2 and 3 involve arithmetic operations on the selected data and output of the results. An example of the ouput of Part 2 and a more detailed explanation of the program are contained in Appendix 6.2.

1.5.2 Statistical Package for the Social Sciences

The large quantity of data generated by Part 2 of the flagging program may be summarized by means of computer programs which have been developed as "pre-packaged products". An example of such a "package" is SPSS (the Statistical Package for the Social Sciences). SPSS is a system of computer programs used for the analysis of data. It enables the user to perform a variety of data transformations and statistical procedures in a simple and convenient manner. The Networks Unit of the Hydrology and Monitoring Section has developed applications of SPSS to manipulate and summarize the results from Part 2 of the flagging program which are either on tape or disk files. These SPSS programs are capable of performing a variety of statistical procedures. For a complete listing and discussion of all the available procedures the reader should consult the SPSS manual[8].

2.0 METHODS OF DATA ANALYSIS

2.1 SELECTION OF THE DATA BASE

A great deal of care was taken in the selection of the 1978 data base for testing the flagging procedure since mistakes at the data selection stage could seriously affect the validity of the results obtained. The four main factors considered in selecting data that satisfied the study objective were:

a) water quality variables;
b) data availability;
c) stations;
d) data limitations.

2.1.1 Water Quality Variables

Water quality variables collected routinely at stations in the Provincial Water Quality Network during 1978 are listed in Table 1. Several of these have been excluded from analysis simply because Objectives do not exist for them, e.g. biochemical oxygen demand. A second group of variables was excluded because their Objectives could not be quantified and therefore could not be flagged by the computer program. Alkalinity is an example of a variable in this group. The Objective states: "Alkalinity should not be decreased by more than 25% of the natural concentrations."[5] The difficulty is that the value of "natural" concentration is generally unknown. Most of the remaining variables were available for input to the flagging programs, limited only by their availability at the stations that were selected. The water quality variables included in this report are listed in Table 2.

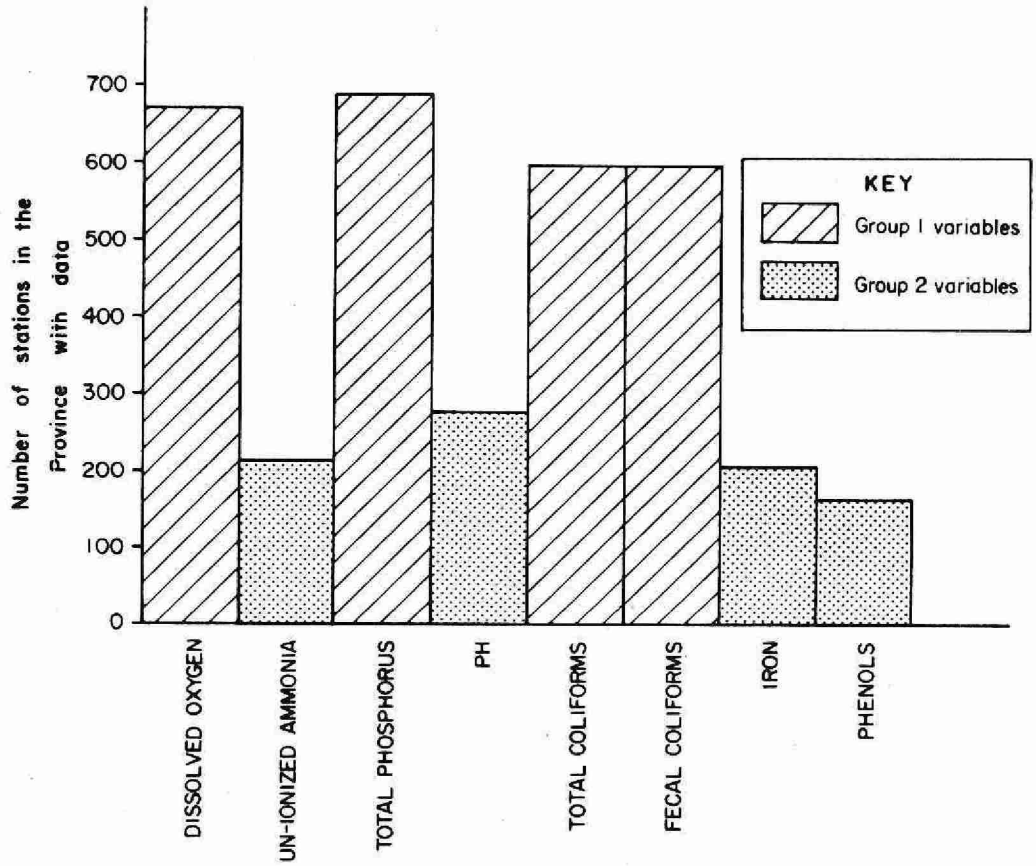
TABLE 2. WATER QUALITY VARIABLES INCLUDED IN THE REPORT

Variable	Problem Represented	Main Uses Affected
total phosphorus	nutrient enrichment	recreation, aquatic life
total coliforms fecal coliforms	bacteriological contamination	recreation, water supply
un-ionized ammonia pH iron phenols dissolved oxygen	toxicity	aquatic life

2.1.2 Data Availability

Figure 3 illustrates the number of stations in the Province reporting data in 1978, for the eight water quality variables discussed in this report. Two distinct groups are apparent, namely: variables with data at most stations (Group 1), and variables with data at about one-half the stations or less (Group 2). The pattern of data availability in each major drainage basin was similar to that for the Province as a whole. The Group 1 variables, dissolved oxygen, total phosphorus, total coliforms, and fecal coliforms, were reported at the majority of stations in each drainage basin. Data for the Group 2 variables, un-ionized ammonia, pH, iron, and phenols were reported at less than one-half of the stations in most of the drainage basins. The Group 2 variables were sampled primarily at stations which measured the effects of industrial and mining discharges in northern Ontario and at surveillance and industrial stations in southern Ontario.

Figure 3. Data availability for Ontario.



2.1.3 Stations

Out of a total of 832 active stations in the Provincial Water Quality Network in 1978, 760 were considered to be representative of a wide variety of water quality conditions in Ontario. The different classes of stations and their approximate distributions have already been presented in Section 1.3.

Stations that were verified by Regional staff to be in a mixing zone downstream of a major point source were excluded from the analysis because they were unrepresentative of water quality in the area. In cases where the length of the mixing zone was unknown, then a station was excluded from the analysis if it was less than 10 km

downstream of a point source. The arbitrary choice of 10 km probably exceeds the actual mixing-zone length of most point sources, therefore some valid stations may have been excluded. This is not considered to be a major problem since less than 1% of the active stations have been excluded for this reason. Furthermore, a second station is very often suitably located further downstream of the excluded station.

There is a possibility that some major point sources were not identified. Consequently, some unrepresentative stations that were in mixing zones may have been included. Since only generalized or pooled results are discussed in this report (as opposed to individual station results), the interpretation and conclusions will be largely unaffected by errors of this type.

Finally, two drainage basins were selected to illustrate an application of the flagging procedure - Lake Superior (39 stations) and Grand River (48 stations). These two basins were chosen because it was believed that the contrasting nature of water quality in these basins would best illustrate the capabilities of the flagging procedure.

2.1.4 Data Limitations

In the example application of the flagging procedure to identify water quality problems, it has been assumed that:

1) the water quality data used in the report were sampled in a representative fashion and analyzed correctly; and
2) the failure of a test result to meet an Objective for any variable is considered equal in importance.

In addition to these assumptions there were characteristics of the data which affected the interpretation. These are listed below:

1) The sample collection frequency of total coliforms and fecal coliforms did not meet the requirements as stated in "Water Management",[5] therefore results for these variables are only <u>an indication</u> of bacteriological water quality.

2) Dissolved oxygen concentrations are probably biased high (better quality). This is because the practice of daytime sampling is not representative of the day-night cycle of dissolved oxygen concentrations.[9]

3) The flagging statistics for phenols are probably slightly biased towards poorer quality due to the inclusion of some test results that were reported as "less than detection limit".

2.2 PROVINCIAL WATER QUALITY OBJECTIVES

The water quality Objectives used in this report were obtained from Table 1 of the Ministry's "Water Management" publication[5] (Table 3). These Objectives were stored on a computer file of the Sample Information System known as the Station Supplementary File (SSF). Although this file has the capacity for storing criteria for 21 different water uses at two levels (permissible and desirable), only the criteria representing two combined water uses were used for this report, namely: the protection of aquatic life and recreation. The reasons for selecting these uses are stated in the Goal for Surface Water Management, "Water which meets the water quality criteria for aquatic life and recreation ... will be suitable for most other beneficial uses, such as drinking water and agriculture."

TABLE 3. PROVINCIAL WATER QUALITY OBJECTIVES USED IN THE REPORT*

Variable	Objective
dissolved oxygen	table
un-ionized ammonia	table
phenols	1 ug/L
total phosphorus**	.030 mg/L
pH	6.5 - 8.5
total coliforms	1000/100 ml
fecal coliforms	100/100 ml
iron	300 ug/L

* from "Water Management", (p.32-43)

** phosphorus guideline stated is for rivers and streams, not lakes.

Most criteria stored on the SSF, consist of a single value which is compared directly to each test result. Some variables, however, require special treatment, namely pH, un-ionized ammonia (expressed as N) and dissolved oxygen. When these variables are encountered in the flagging program, the SSF is by-passed and special calculations are performed by the program as described next.

The Objective for pH is that "The pH should be maintained within the range of 6.5 and 8.5." In this case, these values are compared to each test result. Non-conformance occurs if the pH test result is greater than 8.5 or less than 6.5.

The Objective for ammonia is that "Concentrations of un-ionized ammonia should not exceed 0.02 mg/L for the protection of aquatic life." Un-ionized ammonia is not collected routinely in the Provincial Water Quality Monitoring Network. The flagging program calculates this value using a table (ref. #5, page 32) and the variables: filtered ammonia (expressed as N), pH and temperature (when available). The calculated un-ionized ammonia value is then compared to the criterion value in order to determine conformance.

A single Objective for dissolved oxygen does not exist. Instead, an Objective is calculated by the program on the basis of water temperature for either cold water or warm water biota (ref. #5, page 33). This value is then compared to each test result and non-conformance recorded if the dissolved oxygen concentration of the sample is less than the Objective. For the purpose of this report, only the Objective for cold water biota was used.

In all the cases where another variable ("secondary" variable) is required to calculate an Objective (i.e., un-ionized ammonia and dissolved oxygen), no calculation is performed for a sample unless there are data for all the required input variables. For example, un-ionized ammonia will not be calculated unless there are data for filtered ammonia, pH and temperature for the same sample.

2.3 THE FLAGGING PROGRAM

As outlined earlier, the program consists of three parts: Part 1 - SIS selective retrieval, Part 2 - tabular reports, and Part 3 - summary bar charts.

The SIS selective retrieval, initiated by means of a general SIS retrieval request form, can be made in a variety of ways (e.g. drainage basin, or individual station number, for various time periods). Any single run is limited to a maximum of twenty variables including all the appropriate "secondary" variables referred to above. The selected data from Part 1 may be stored on magnetic tape or disk, and/or it may be printed.

The second Part of the program compares data selected from Part 1 to the Provincial Water Quality Objectives that are stored in a file of the SIS and produces a tabular report containing conformance statistics.

Parts 1 and 2 of the flagging program produced the results used in this report. The third part of the program and some other optional

aspects of Parts 1 and 2 have not been included at this time, but will be explored in future reports. A more detailed description of the flagging program is contained in Appendix 6.2.

2.4 POOLED EXCEEDENCE

As a first step in identifying problem areas, a statistic called "pooled exceedence" (PE) was calculated for each station using SPSS computer programs, (see Appendix 6.2). Pooled exceedence is defined as the percentage of test results at a station that do not meet the Objectives for a group of variables. PE was calculated from the group of variables listed in Table 2. An advantage in using pooled exceedence is that it provides a concise statistic that is simple to calculate and can readily be compared among stations and/or groups of stations.

A pooled-exceedence value of 0% at a station means that every variable met its Objective. This represents the most desirable water quality. On the other hand, a value of 100% indicates that no variable met its Objective. This, of course, represents the least desirable water quality. Pooled-exceedence values in the range of 1-99% means that some variables did not meet their respective Objectives some of the time.

Pooled exceedence can be used to identify water quality problems at individual stations or in larger areas, such as river or major drainage basins. In this regard, it provides a useful aid in establishing priorities for possible remedial action or further studies. To illustrate one possible use of pooled exceedence in the identification of non-conformance problems, PE statistics were calculated for each of the selected stations in the Lake Superior and Grand River basins and cumulative frequency distribution curves plotted (figures 4 and 5, respectively).

A curve, similar to the one shown for Lake Superior (Figure 4) would indicate that there are relatively few stations in a basin that have

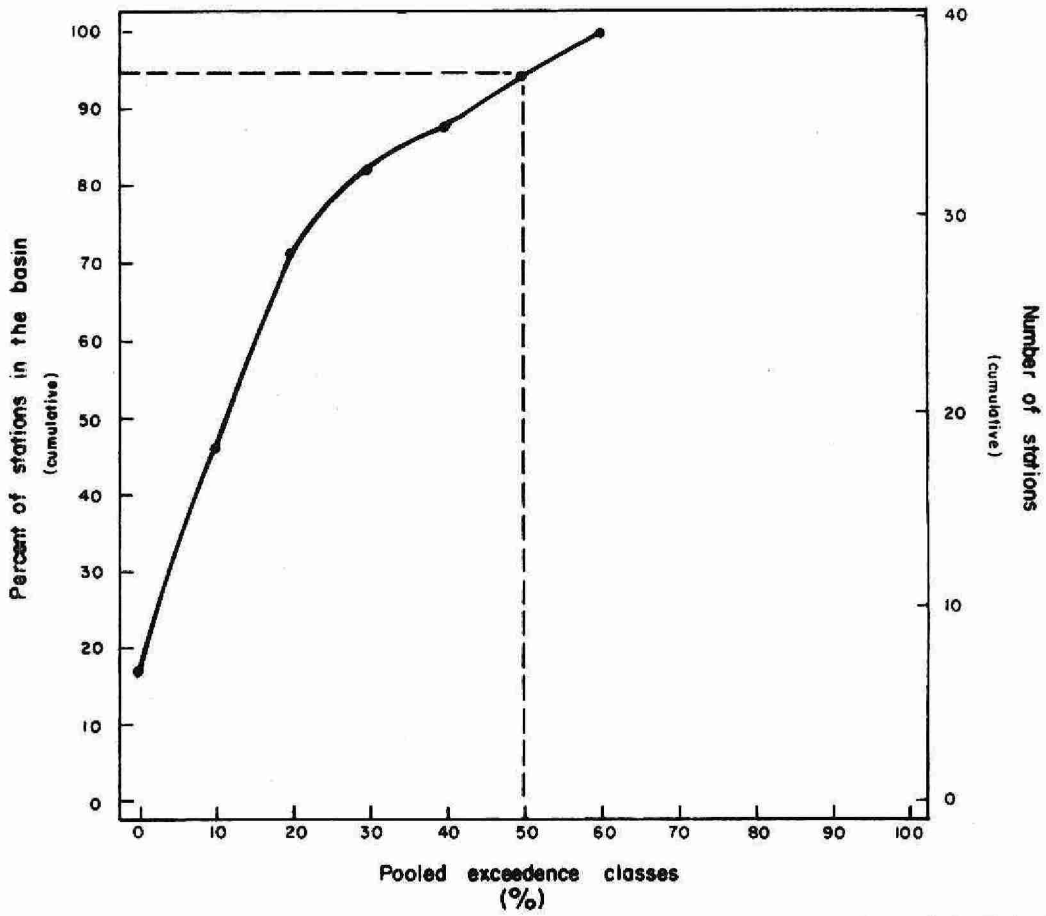


Figure 4. Cumulative frequency distribution of pooled exceedence for selected stations in the Lake Superior basin.

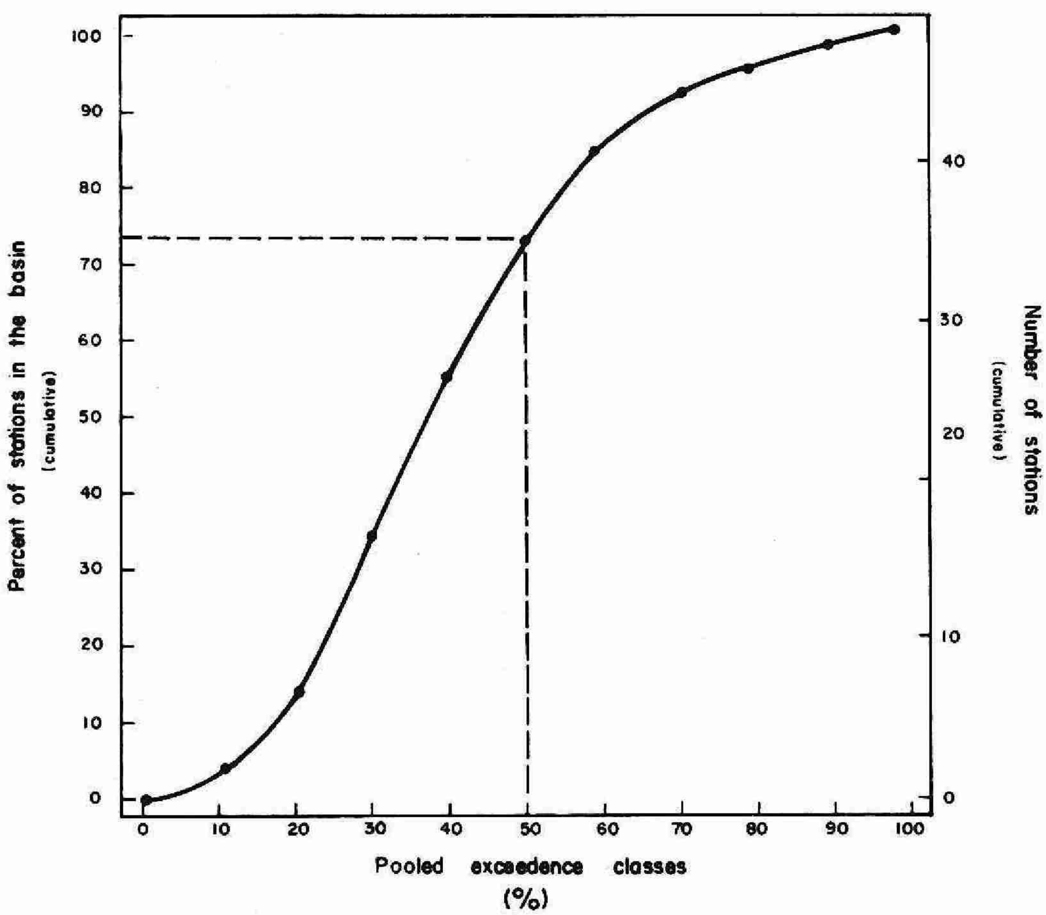


Figure 5. Cumulative frequency distribution of pooled exceedence for selected stations in the Grand River basin.

"significant" non-conformance problems*. On the other hand, a curve similar to the one shown for the Grand River (Figure 5) would indicate significant non-conformance problems at several stations in a basin. In this example, approximately 5% of the stations in the Lake Superior and 27% of the stations in the Grand River basin have significant non-conformance problems (according to the arbitrary definition). Furthermore, the highest pooled exceedence value at a station is 98% in the Grand River basin compared to 59% in the Lake Superior basin.

Pooled exceedence thus indicates that there is a greater percentage of stations with significant non-conformance problems in the Grand River basin than in the Lake Superior basin. Also, the magnitude of the problem is greater in the former basin. This information could then be used to establish priorities for remedial action or to direct the thrust of further investigations.

2.5 PERCENT EXCEEDENCE

The pooled-exceedence statistics indicate the degree to which stations, or groups of stations, do not meet Objectives but do not indicate which variables at the stations are in non-conformance. To obtain this information the "percent exceedence" may be examined for each variable in turn. The percent exceedence is defined as the percentage of test results at a station, that do not meet the Objective for a particular water quality variable.

The interpretation of percent exceedence data is similar to that of pooled exceedence, keeping in mind that percent exceedence refers to a single variable. For example, a percent exceedence value of zero for variable "X" means that every test result met the Objective for "X", i.e., total conformance. On the other hand, a percent exceedence value of 100 indicates that no test result met the Objective, i.e., total non-conformance.

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* *A "significant" non-conformance problem is arbitrarily considered to be a station with a pooled exceedence value greater than 50%.*

The use of the percent exceedence statistic to identify water quality non-conformance problems is straightforward and may be applied to individual stations or groups of stations. Expanding on the Lake Superior and Grand River example presented for the pooled exceedence statistic, percent exceedence values were examined for the eight variables used previously at each of the stations in these two basins. The distribution of the stations in each of two percent exceedence classes (0% and 100%) was determined for each variable, in each basin, and histograms plotted (figures 6 and 7).

The pooled exceedence statistics indicated that there were relatively few stations with significant non-conformance problems in the Lake Superior basin (Figure 4). The percent exceedence statistics confirm this fact (Figure 6). The variables dissolved oxygen, un-ionized ammonia, pH, total coliforms and fecal coliforms were in total conformance with the Objectives (0% exceedence) at the majority of the stations in the basin. Total non-conformance (100% exceedence) occurred at less than 5% of the stations for the variables: total phosphorus, total coliform and fecal coliform. These non-conformance problems occurred primarily at stations downstream of industrial and municipal point source discharges.

In the Grand River basin, the pooled exceedence statistic indicated that there were significant non-conformance problems at several stations (Figure 5). The variables primarily responsible can be observed in Figure 7. Forty-two percent of the stations in the Grand River basin are in total non-conformance of the phosphorus guideline. In addition, the percentage of stations in the Grand River basin which are in total conformance of the Objectives is

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* *see discussion on limitations for total coliform and fecal coliform data on page 14.*

quite small for several variables (i.e., total coliform 2%; fecal coliform 11%; and phenols 15%). The variables phosphorus and iron are never in total compliance at a station. On the other hand dissolved oxygen conformance in the Grand River basin was good, i.e., 95% of stations in total conformance and 0% in total non-conformance.

The non-conformance problems in the Grand River basin are due to several causes, such as municipal and industrial point source discharges and runoff from urban and agricultural land. The Ministry of the Environment and co-operating agencies are presently in the process of completing a comprehensive study which examines the above-mentioned problems in detail and makes recommendations on how to improve water quality in the basin.

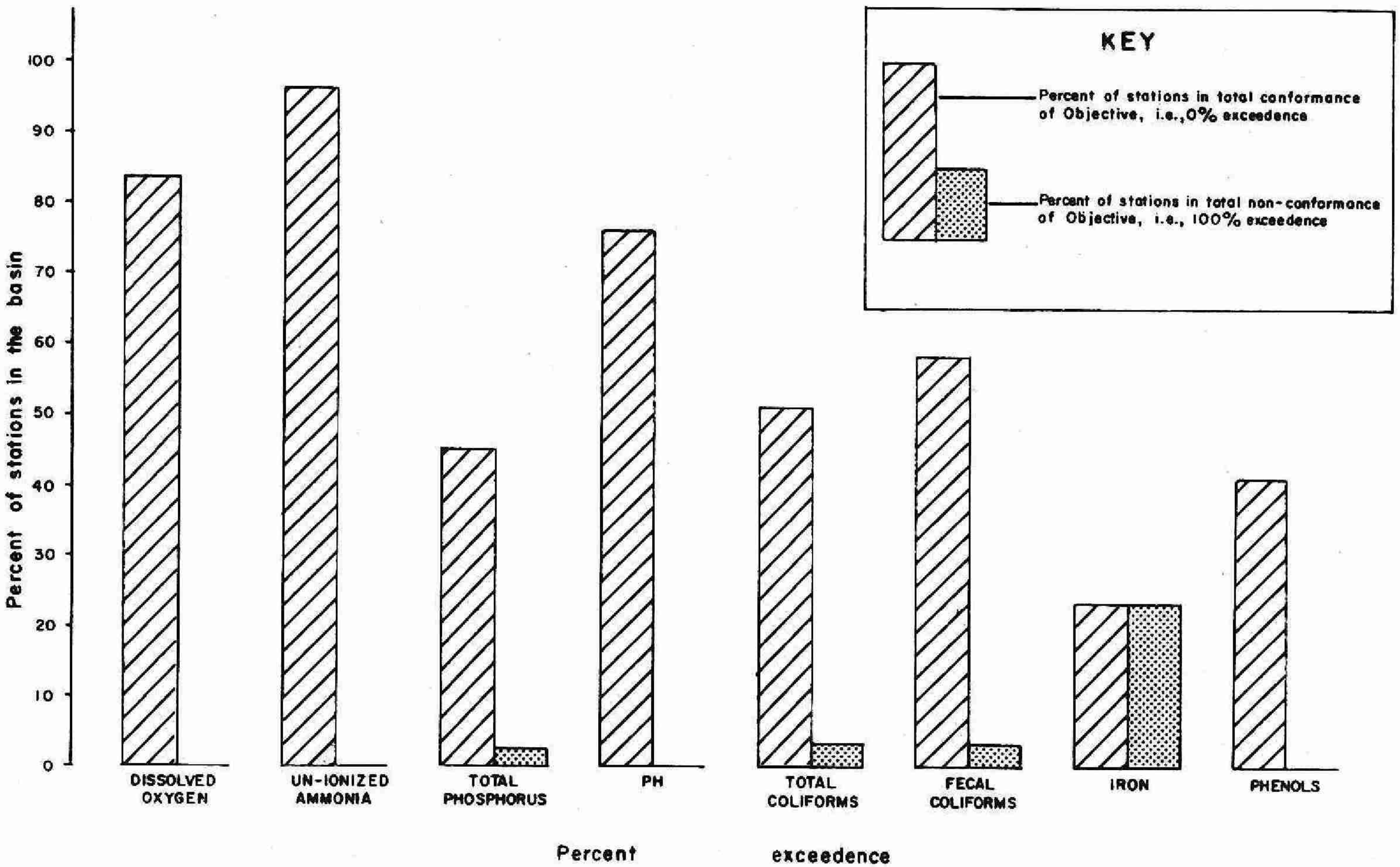

Figure 6. Total conformance and total non-conformance at selected stations in the Lake Superior basin.

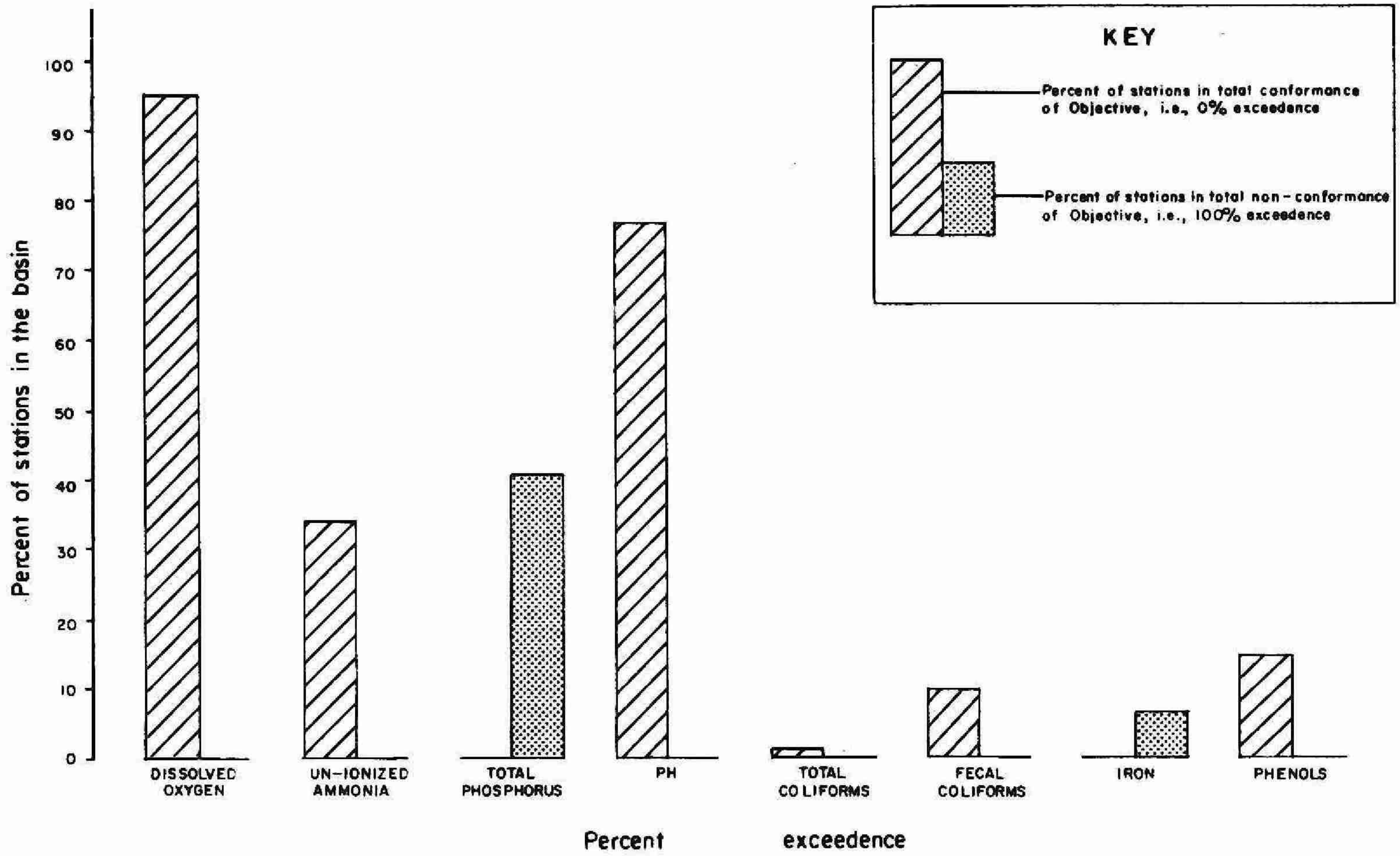

Figure 7. Total conformance and total non-conformance at selected stations in the Grand River basin.

3.0 EVALUATION AND RECOMMENDATIONS

3.1 EVALUATION OF THE FLAGGING PROCEDURE

The flagging procedure discussed in this report is an effective tool that can be used to identify water quality problems in a given area, but the procedure is dependent to a great extent on how well the data represents in-situ water quality. The strength and substance of the findings are directly affected by the operating assumptions and data limitations. The importance of the selection of representative water quality variables and stations cannot be over-emphasized.

The procedure itself is easy to apply, the most difficult step being the selection of representative water quality variables and stations. The computer program which produces the flagging results operates satisfactorily. Once the initial data selection step is completed, the results may be obtained in a matter of one or two days. The preparation of the data summaries using SPSS programs is the most time-consuming step.

The pooled exceedence statistic was useful in combining the effects of several water quality variables into a single number for a station which was then used to identify areas of significant non-conformance. The percent exceedence statistic was effective in identifying problem variables and the locations where non-conformance problems occurred. Both statistics may be applied on a broad scale, e.g., a river basin or on a narrow-scale, such as individual stations.

Two aspects of the procedure should be improved, namely:

1) the method of selecting representative stations (e.g. problems with determining the length of mixing zones); and
2) the Objectives which cannot be quantified and therefore cannot be "flagged" by the computer programs (e.g. alkalinity).

3.2 RECOMMENDATIONS

1) Work should continue to improve technical aspects of the water quality flagging procedure.

2) The flagging procedure should be used to prepare reports as follows:

   a) an inventory of non-conformance at stations in the Provincial Water Quality Monitoring Network, 1974-1978.

   b) annual reports identifying major water quality problems;

   c) specific-area reports, e.g., mining areas, sewage treatment plants, industries, etc.;

   d) specific-variable reports, e.g., metals, arsenic, total phosphorus, etc.

4.0 GLOSSARY

Conformance is a term used to designate a test result or a set of test results that meet a specific water quality Objective. The term "conformance" may be used to describe the following three situations:

1) a test result is equal to or less than the Objective; or

2) a test result is equal to or greater than the Objective; or

3) a test result is within a specified range.

The first situation applies to the majority of water quality variables discussed in this report, namely: un-ionized ammonia, total phosphorus, total coliforms, fecal coliforms, iron and phenols. The second and third situations apply to the variables dissolved oxygen and pH, respectively.

Non-conformance is a term used to designate a test result or a set of test results that fail to meet a specific water quality Objective. See "conformance".

Objectives, as used in this study, are a set of numerical criteria designed for the protection of aquatic life and recreation in and on the water. The Objectives used in this report are found in the publication "Water Management."[5]

Percent exceedence is a statistic calculated in the flagging procedure and is defined as the percentage of test results at a station that do not meet the Objective for a particular water quality variable.

Pooled exceedence is a statistic calculated in the flagging procedure and is defined as the percentage of test results at a station that do not meet the Objectives for a selected group of water quality variables.

Test result is the numerical value obtained from the chemical or physical analysis of a water quality sample. Three examples of individual test results are as follows:

1) 6.8 (pH);
2) 8.1 mg/L (dissolved oxygen); and
3) 250 mF/100 ml (fecal coliforms).

Water quality flagging is a procedure involving the calculation of non-conformance statistics, e.g., percent exceedence and pooled exceedence, to describe water quality.

Water quality variable is a constituent or a characteristic of stream and/or lake waters. Examples of water quality variables are total phosphorus (a constituent) and pH (a characteristic).

5.0 REFERENCES

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6.0 APPENDICES

APPENDIX

6.1 RIVERS AND LAKES SAMPLED IN THE PROVINCIAL WATER QUALITY MONITORING NETWORK

RIVERS AND LAKES SAMPLED IN THE PROVINCIAL WATER QUALITY MONITORING NETWORK

(A) Lake Superior

Lake Superior	Current River
Montreal River	McVicar Creek
Agawa River	McIntyre River
Magpie River	Neebing River
White River	Kamihistiquia River
Pic River	Pigeon River
Little Pic River	Whitefish Bay
Aguasabon River	Goulais River
Nipigon River	Harmony River
Black Sturgeon River	Batchawana River

(B) Georgian Bay

Pottawatomi River	North River
Sydenham River	Severn River
Telfer Creek	Muskoka River
Orchard Creek	Moon River
Bighead River	Boyne River
Beaver River	McCurry Lake
Silver Creek	Seguin River
Pretty River	Magnetawan River
Batteau River	Key River
Nottawasaga River	Pickerel River
Wye River	French River

(C) Lake St. Clair

Little River	Ruscom River
Manning Drain	Thames River
Puce River	Sydenham River
Belle River	Clay Creek

(D) Lake Ontario

Chippawa Canal
Welland River
Welland Ship Canal
Twelve Mile Creek
Twenty Mile Creek
Forty Mile Creek
Redhill Creek
Spencer Creek
Grindstone Creek
Bronte Creek
Fourteen Mile Creek
Oakville Creek
Rattray Marsh
Credit River
Etobicoke Creek
Mimico Creek
Humber Creek
Don River
Highland Creek
Rouge River
Duffins Creek
Lynde Creek
Pringle Creek
Oshawa Creek
Harmony Creek
Bowmanville Creek
Orono Creek
Graham Creek
Ganaraska River
Gage Creek
Brookside Creek
Shelter Valley Brook
Colborne Creek
Salem Creek
Proctors Creek
Smithfield Creek
Consecon Creek
Bloomfield Creek
Black River
Millhaven Creek
Collins Creek
Carruther Creek

(E) Lake Huron

Hickory Creek
The Cut
Ausable River
Bayfield River
Maitland River
Lucknow River
Pine River
Litle Sauble River
Saugeen River
Sauble River
Stakes River
Spring Creek

(F) St. Lawrence River

Little Cataraqui Creek
Cataraqui River
Gananoque River
Raisin River

(G) North Channel

St. Mary's River	Thessalon River
Big Carp River	Mississagi River
Fort Creek	Blind River
Root River	Serpent River
Garden River	Spanish River

(H) Lake Erie

Turkey Creek	Big Creek
Canard River	Lynn River
Sturgeon River	Foley Creek
Muddy Creek	Centre Creek
Dutton Drain	Nanticoke Creek
Kettle Creek	Sandusk Creek
Catfish Creek	Grand River
Bit Otter Creek	

(I) Bay of Quinte

Picton Creek	Moira River
Demorestville Creek	Salmon River
Sawquin Creek	Napanee River
Trent River	Wilton Creek

(J) Ottawa River

Ottawa River	Mattawa River
Rideau River	Montreal River
Green Creek	Farr Creek
Carp River	Wabi Creek
Mississippi River	Blanche River

(K) Hudson Bay

Rainy River	Moose River

APPENDIX

6.2 TECHNICAL DESCRIPTION OF THE FLAGGING PROGRAM

DESCRIPTION

The flagging program consists of three parts: Part 1 - SIS selective retrieval, Part 2 - tabular reports, and Part 3 - summary bar charts. The SIS selective retrieval can be made in a variety of ways, e.g., by region, drainage basin or station number. Any single run is limited to a maximum of twenty variables including all secondary variables that are required. The selected data may be stored on magnetic tape or disk, and/or it may be printed. The second Part of the program compares data selected from Part 1 to the Provincial Water Quality Objectives which are stored on a computer file of the SIS. A series of tables are printed with a format of one station per page (Figure 8).

Station identification information appears at the top of the page (Figure 8) with the water quality uses immediately beneath (e.g. Aquatic and Recreation Protection). Water quality variables are listed vertically on the left side of the page (maximum twenty). The symbol "%" gives the percentage of water quality test results for each variable that exceed the appropriate water quality Objective. This calculation is performed if the number of samples obtained ("NO OBTN") is greater than or equal to the number of samples expected ("NO EXPT") as specified by the user. The symbol "AVE" is a measure of the magnitude of exceedence at a station but was not used in this report. The symbol "LVL" refers to the three possible levels of comparison to the guidelines, namely: permissible (P), desirable (D), and arbitrary or user defined (A). The results of Part 2 may be stored on computer tape for subsequent analysis.

The third part of the program, which is optional, was not used to produce this report.

The results of the flagging program may be printed and/or stored on computer tape. This tape contains the "percent exceedence", "number of samples" and other data for the water quality variables selected for the initial computer run. As a first step in the summary

SAMPLE INFORMATION SYSTEM
B.O.W./SITE : LAKE SUPERIOR
SAMPLE POINT: OFF MOUTH OF RIVER
STATION TYPE: LAKE

WATER QUALITY CRITERIA STATION SUMMARY REPORT
SAMPLES NOT MEETING OBJECTIVES

STATION ID: 01-0000-000-01

TIME PERIOD: 78-01-01 TO 78-12-31

COMPLIANCE STATISTICS FOR VARIOUS WATER USES

WATER QUALITY VARIABLE	SAMPLES NO EXPT	SAMPLES NO OBTN	LVL	AQUATIC & RECREATION PROTECTION %	AQUATIC & RECREATION PROTECTION AVE
DISSOLVED OXYGEN	2	10	P	30	1.50
TOTAL PHOSPHORUS	2	10	P	80	0.030
PH	2	5	P	0	0
TOTAL COLIFORMS	2	9	P	56	38840
FECAL COLIFORMS	2	9	P	44	1635
IRON	2	5	P	60	0.167

Figure 8. Example output of flagging program.

procedure, the data are transferred by means of an SPSS program from tape to disk storage in order to facilitate subsequent analysis. Using another SPSS program a subset of representative stations is selected as the final data base for the report.

Station selection is placed at this point in the procedure rather than at the beginning to provide maximum flexibility in choosing representative stations in a cost-effective manner. If the selection of a particular set of stations turns out to be wrong (e.g. insufficient number of samples) then another selection of stations may easily be made from the disk data-set. Placement of station selection at the beginning of the flagging procedure, however, would require running the entire program over again to obtain results for a different set of stations.

Pooled exceedence (PE) is calculated for each station using the following equation.

$$PE = \frac{\sum_{i=1}^{J} (Ni \times Vi)}{\sum_{i=1}^{J} Ni} \qquad (1)$$

where: Ni is the number of test results for the ith water quality variable;
Vi is the percentage of test results not meeting the test results for the ith water quality variable; and
J is the number of water quality variables included in the calculation.

An example calculation of pooled exceedence, using the data shown in Figure 8, follows.

N, the number of test results for each variable, is listed in Figure 8 under the symbol "NO OBTN". V, the percentage of test results exceeding the Objectives, is listed under the symbol "%".

The first step in the calculation of pooled exceedence is the selection of variables that have four or more test results. A minimum of four variables with sufficient data are required before pooled exceedence may be calculated. In this example, eight variables have sufficient data and will be included in the calculation.

These data are summarized next:

Variable	N	V
dissolved oxygen	10	30%
total phosphorus	10	80%
pH	5	0%
total coliforms	9	56%
fecal coliforms	9	44%
iron	5	60%

J, the number of water quality variables included in the calculation, is equal to 6.

Using the preceding equation,

$$PE = \frac{\sum_{i=1}^{6} (Ni \times Vi)}{\sum_{i=1}^{6} Ni} \qquad (2)$$

$$PE = \frac{(10x30)+(10x80)+(5x0)+(9x56)+(9x44)+(5x60)}{10 + 10 + 5 + 9 + 9 + 5} \qquad (3)$$

$$PE = \frac{2300}{48} = 47.9$$

Rounded to the nearest percent, pooled exceedence is equal to 48%.